

Aerodynamic Analysis of Airfoil in Vertical Axis Wind Turbine

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Abstract— The main objective of this study is to better understandings the effects of various parameters like airfoil shape/type, Reynolds number, angle of attack, wind speed on the performances of these turbines. These effects are investigated on a straight bladed vertical axis wind turbine which leads to variations of pressure distribution on upper and lower surface of the blade section. The work can be started by Direct Design method of specified section geometry and the calculation of pressure and performance by theoretically. This could be compared with numerically by using SOLID WORKS as modelling and ANSYS CFX as solver for NACA 00xx, NACA xxxxx at different angle of attack and different velocities. From these the pressure and force distribution of airfoil section NACA xxxxx and NACA 00xx were calculated and the power coefficient of the former one increased than later one. This would lead changing of airfoil thickness may cause the power coefficient.

Key words: Reynolds Number, Airfoil Shape, Angle of Attack, Straight Bladed Vertical Axis Wind Turbine, NACA (National Advisory Committee for Aeronautics)

I. INTRODUCTION

The economic development and viable use of horizontal axis wind turbine would, in the future be limited, partly due to the high stress loads on the blades. It is recognized that, although less efficient, vertical axis wind turbine do not suffer so much from the constantly varying gravitational loads that limit the size of horizontal axis turbines. Wind energy depends on the following factor which is Wind speed, Wind direction, Seasonal climate, blade profile, Reynolds number, solidity etc. Moreover the profile has vital role in production of wind energy [1, 4]. Once the profile subjected to face the different velocity it would have experienced pressure on its surface[7,8] which act vital role in power production. Before that the aero dynamics of the wing section has to be done by Sheldahl and Klimas [2,3]. Argen[6] did a Analytical solution for a single turbine in vertical axis wind turbine in two dimensions mentioned the aerofoil is one of the key role in power production.

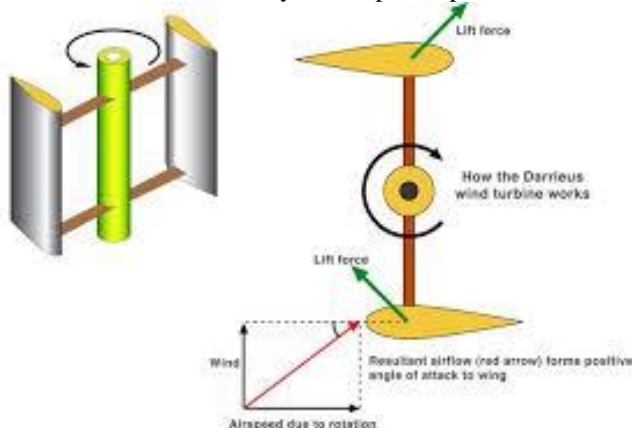


Fig. 1: Straight bladed darrieus turbine.

II. RAPID ESTIMATION OF PRESSURE DISTRIBUTIONS

In the discussion that follows, the term "pressure distribution" is used to signify the distribution of the static pressures on the upper and lower surfaces of the airfoil along the chord. The term "load distribution" is used to signify the distribution along the chord of the normal force resulting from the difference in pressure on the upper and lower surfaces. The pressure distribution about any airfoil in potential flow may be calculated accurately by a generalization of the methods. Although this method is not unduly laborious, the computations required are too long to permit quick and easy calculations for large numbers of airfoils. The need for a simple method of quickly obtaining pressure distributions with engineering accuracy has led to the development of a method combining features of thin- and thick-airfoil theory. This simple method makes use of previously calculated characteristics of a limited number of mean lines and thickness distributions that may be combined to form large numbers of airfoils. Thin-airfoil theory shows that the load distribution of a thin airfoil may be considered to consist of:

- 1) A basic distribution at the ideal angle of attack and
- 2) An additional distribution proportional to the angle of attack as measured from the ideal angle of attack.

The first load distribution is a function only of the shape of the thin airfoil, or (if the thin airfoil is considered to be a mean line) of the mean-line geometry. Integration of this load distribution along the chord results in a normal-force coefficient which, at small angles of attack, is substantially equal to a lift coefficient C_{li} , which is designated the ideal or design lift coefficient. If, moreover, the camber of the mean line is changed by multiplying the mean-line ordinates by a constant factor, the resulting load distribution, the ideal or design angle of attack at and the design lift coefficient C_{li} may be obtained simply by multiplying the original values by the same factor. For positive design lift coefficients, these velocity-increment ratios are positive on the upper surface and negative on the lower surface; the opposite is true for negative design lift coefficients.

The second load distribution, which results from changing the angle of attack, is designated herein the "additional load distribution" and the corresponding lift coefficient is designated the "additional lift coefficient." This additional load distribution contributes no moment about the quarter-chord point and, according to thin-airfoil theory, is independent of the airfoil geometry except for angle of attack. The additional load distribution obtained from thin-airfoil theory is of limited practical application, however, because this simple theory leads to infinite values of the velocity at the leading edge. This difficulty is obviated by the exact thick-airfoil theory which also shows that the additional load distribution is neither completely

independent of the airfoil shape nor exactly a linear function of the lift coefficient. For this reason, the additional load distribution has been calculated. These data are presented in the form of velocity-increment ratios ($\Delta v_a/V$) corresponding to an additional lift coefficient of approximately unity. For positive additional lift coefficients, these. Velocity-increment ratios are positive on the upper surfaces and negative on the lower surfaces; the opposite is true for negative additional lift coefficients. In addition to the pressure distributions associated with these two load distributions, another pressure' distribution exists which is associated with the basic symmetrical thickness form or thickness distribution of the airfoil. The local velocity ratio is always positive and is the same for corresponding points on the upper and lower surfaces of the thickness form. The velocity distribution about the airfoil is thus considered to be composed of three separate and independent components as follows:

- The distribution corresponding to the velocity distribution over the basic thickness form at zero angle of attack
- The distribution corresponding to the design load distribution of the mean line
- The distribution corresponding to the additional load distribution associated with angle of attack.

The velocity-increment ratios ($\Delta v/V$) and $\Delta v_a/V$ corresponding to components (2) and (3) are added to the velocity ratio corresponding to component (1) to obtain the total velocity at one point, from which the pressure coefficient C_p is obtained;

$$\text{Thus, } C_p = \left(\frac{v}{V} \pm \frac{\Delta v}{V} \pm \frac{\Delta v_a}{V} \right)^2 \quad (2.1)$$

When this formula is used, values of the ratios corresponding to one value of x are added together and the resulting value of the pressure coefficient C_p is assigned to the airfoil surface it is the same value of X . The values of v/V and of $\Delta v/V$ in equation (1) should, of course, correspond to the airfoil geometry. "When the ratio $\Delta v_a/V$ has the value of zero, the resulting distribution of the pressure coefficient C_p will correspond approximately to the pressure distribution of the airfoil section at the design lift coefficient C_{li} of the mean line, and the lift coefficient may be assigned this value as a first approximation. The pressure distribution will usually be desired at some specified lift coefficient not corresponding to C_{li} . For this purpose the ratio ($\Delta v_a/V$) must be assigned some value obtained by multiplying the tabulated value of this ratio by a factor $f(\alpha)$. For a first approximation this factor may be assigned the value

$$f(\alpha) = c_l - c_{li} \quad (2.2)$$

Where C_l is the lift coefficient for which the pressure distribution is desired. If greater accuracy is desired, the value of $f(\alpha)$ may be adjusted by trial and error to produce the actual desired lift coefficient as determined by integration of the pressure-distribution diagram.

With the above procedure the pressure coefficient distribution of NACA 0009 and NACA 23018 has been find out which can be illustrated below:

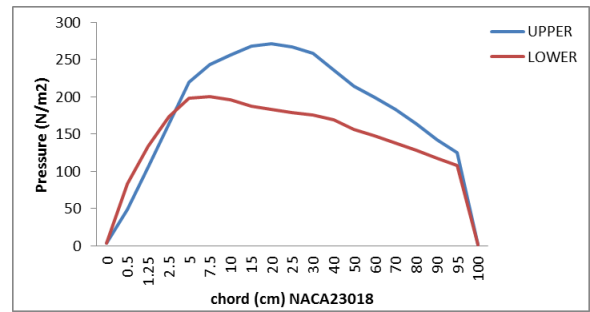


Fig 2.1: Pressure Distribution on NACA 23018

From the fig 2.1 and 2.2 the pressure distribution over an airfoil NACA23018, NACA0009 have been created through the procedure. These shows that the changing of airfoil will directly affect the power production.

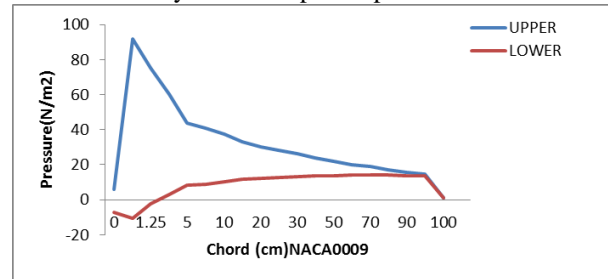
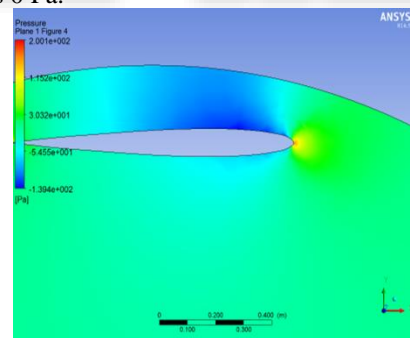


Fig 2.2: Pressure Distribution on NACA 0009

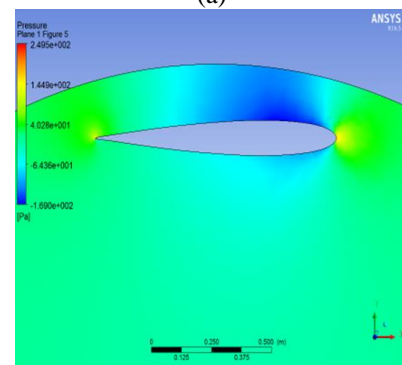
III. NUMERICAL STUDY

The airfoil model for improving power is NACA 0009 and NACA 23018 has been taken and it is numerically analyzed for different velocities.

The fig 3.1 and 3.2 shows pressure distribution over an NACA 0009 and NACA 23018 with the boundary of diameter 4.5 meter and thickness 0.01 m. The inlet velocity is 15 m/s and 20 m/s respectively and opening pressure is 0 Pa.

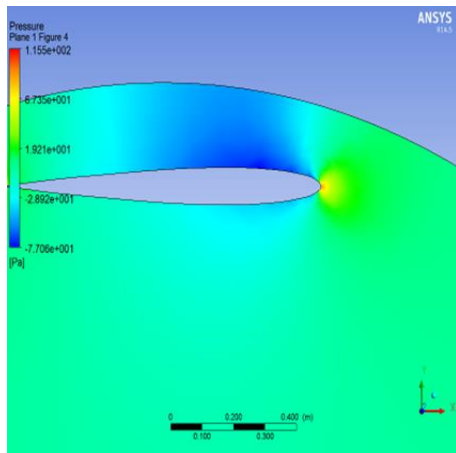


(a)

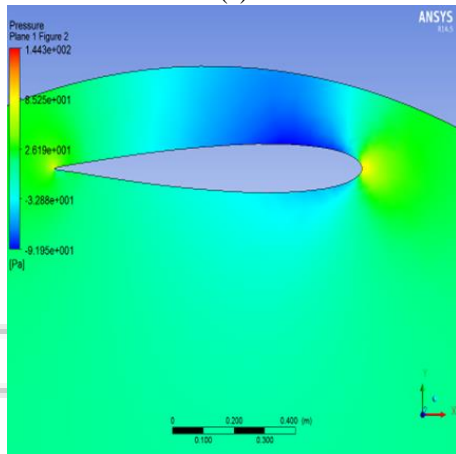


(b)

Fig. 3.1: Pressure distribution on airfoil (a) NACA0009 (b)NACA23018



(a)



(b)

Fig 3.2: Pressure distribution on airfoil (a) NACA0009 (b) NACA 23018

The following table 3.1 shows that pressure distribution of an airfoil for different velocities, which shows that pressure, can vary for different airfoil series. It directly affects the electric power production.

S.No	Profile	Velocity m/s	Pressure(Pa)	
			Max	Min
1	NACA 0009	15	115.5	-77.06
2		20	200	-139
4	NACA 23018	15	144	-91.5
5		20	249	-169

Table 3.1: Pressure distribution on airfoil for different angle of velocity

IV. RESULTS AND DISCUSSION

In order to maximize the rotor power it would therefore be desirable to have both wind speed and pressure drop as large as possible. From the numerical calculation it is obvious that the pressure drop is minimum for NACA 0009 for the velocities of 15m/s and 20m/s are 28 Pa and 61 Pa respectively and for the theoretical pressure drop is 71Pa. So far the power extracted from such airfoil give minimum power. For the purpose of maximizing the power the airfoil thickness has to increase as introducing the airfoil naca23018.this one have the pressure drop of 53Pa and 80 Pa which are maximum than naca0009 and the theoretical pressure drop is 75 Pa for the velocities. Indeed changing of airfoil section would leads to increase the pressure as well as increase the power coefficient.

V. CONCLUSION

A numerical study was carried out to investigate the effects of a blade profile on the performance of a straight bladed Darrieus Vertical Axis Wind Turbine. The numerical results confirm that the blade profile directly affects the performance of the straight-type Darrieus Vertical Axis Wind Turbine, i.e., the high-digit NACA profile provides higher pressure than the low-digit symmetrical NACA profile.

Vertical Axis Wind Turbine with NACA 0009 and NACA 23018 airfoil geometry was analyzed by numerically .The simulation results shows that the pressure can vary for different velocity.

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